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The Effects of Radiation Exposure on Thyroid Function: A Clinical Study

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ABSTRACT

Objective: To evaluate the impact of occupational radiation exposure on thyroid function among healthcare workers exposed to radioactive iodine-131 and X-rays.

Method: A retrospective study of 101 participants divided into three groups: nuclear medicine workers (radioactive iodine-131 exposure), radiology workers (X-ray exposure), and controls. Thyroid hormone levels and ultrasonography results were analyzed. The mean duration of occupational exposure was approximately 10 years.

Results: Nuclear medicine workers showed elevated TSH levels (30% with subclinical hypothyroidism), while radiology workers exhibited reduced thyroid volume. Controls demonstrated no thyroid dysfunction.

Conclusion: Occupational radiation exposure, especially to iodine-131, poses significant risks to thyroid health, underscoring the need for stringent radiation safety and regular monitoring.

Keywords: Radiation exposure, thyroid function, nuclear medicine, hypothyroidism, X-rays.

ÖZET

Amaç: Radyoaktif iyot-131 ve X-ışınlarına maruz kalan sağlık çalışanlarında mesleki radyasyon maruziyetinin tiroid fonksiyonları üzerindeki etkisini değerlendirmek.

Yöntem: Radyoaktif iyot-131'e maruz kalan nükleer tıp çalışanları, X-ışını maruziyeti olan radyoloji çalışanları ve kontrol grubundan oluşan 101 katılımcının dahil edildiği retrospektif bir çalışma. Tiroid hormon düzeyleri ve ultrasonografi sonuçları analiz edilmiştir.Mesleki maruziyet süresinin ortalama 10 yıl olduğu belirlendi.

Bulgular: Nükleer tıp çalışanlarında TSH seviyelerinin yükseldiği (%30 subklinik hipotiroidizm) ve radyoloji çalışanlarında tiroid hacminin azaldığı gözlemlenmiştir. Kontrol grubunda tiroid fonksiyon bozukluğu saptanmamıştır.

Sonuç: Özellikle iyot-131'e maruz kalmak, tiroid sağlığı üzerinde önemli riskler oluşturmaktadır. Bu durum, radyasyon güvenliği ve düzenli takip ihtiyacını vurgulamaktadır.

Anahtar Kelimeler: Radyasyon maruziyeti, tiroid fonksiyonu, nükleer tıp, hipotiroidizm, X-ışınları.

Radiation is an integral part of modern medical practice but also represents a significant environmental exposure that can have potentially harmful effects on human health. The number of individuals occupationally exposed to radiation, particularly in fields such as nuclear medicine, radiology, and radiotherapy, is increasing steadily. This has made the investigation of the long-term health effects of occupational radiation exposure a critical issue.[1]

Radiation affects various organs through mechanisms such as DNA damage, cellular apoptosis, and mutations. These effects can result in both acute and chronic health problems. Among these, the thyroid gland is particularly sensitive due to its critical role in metabolic regulation and its dependency on iodine for hormone production. This makes the thyroid gland especially vulnerable to ionizing radiation such as radioactive iodine-131 (I-131) and X-rays.[2]

Radioactive iodine-131 is widely used in nuclear medicine and selectively binds to the thyroid gland, potentially causing cellular damage and disruption of thyroid function. Previous studies have shown that high-dose radiation exposure is associated with thyroid cancer, hypothyroidism, and nodule formation [3]. However, the effects of long-term, low-dose exposure on thyroid function remain less understood. This knowledge gap complicates the risk assessment for individuals exposed to low-dose occupational radiation.

Healthcare professionals working in fields such as nuclear medicine and radiology are among the primary groups exposed to ionizing radiation. Nuclear medicine workers, in particular, frequently handle radioactive substances as part of diagnostic and therapeutic procedures.[4] Similarly, radiology workers face occupational risks due to the extensive use of X-ray radiation. These exposures affect thyroid function through mechanisms such as apoptosis, DNA breaks, and oxidative stress. However, the subclinical effects of low-dose radiation exposure are often overlooked, and its long-term consequences are insufficiently assessed.[5]

Although prior studies have clearly demonstrated the association between high-dose radiation and thyroid disorders, findings regarding low-dose exposure are more inconsistent [6].Gaining a better understanding of the effects of low-dose X-rays and radioactive iodine on thyroid function is essential for protecting healthcare workers and mitigating long-term health risks.[7]

This study aims to investigate changes in thyroid function among individuals occupationally exposed to different types of radiation. Specifically, it compares nuclear medicine workers exposed to radioactive iodine-131, radiology workers exposed to X-rays, and a control group with no exposure. Serum thyroid hormone levels and thyroid volume were evaluated to analyze the impact of exposure type and level on thyroid function.

Methods

This study was designed as a prospective observational study to evaluate the effects of occupational radiation exposure on thyroid function. A total of 101 participants from specific occupational groups were recruited and divided into three groups based on the type and level of radiation exposure:

- **Group 1 (Exposed to Radioactive Iodine-131):** This group included nuclear medicine workers who regularly handle I-131 for diagnostic or therapeutic purposes (n = 35).
- **Group 2 (Exposed to X-rays):** This group included radiology workers who are routinely exposed to X-rays in hospital settings (n = 33).
- **Group 3 (Control Group):** Participants in this group had no occupational radiation exposure and were matched by age and gender (n = 33).

The average duration of occupational exposure among participants was approximately 10 years. Therefore, subgroup analysis based on duration categories (<5 years, 5–10 years, >10 years) could not be performed due to data limitations. However, the overall cohort, with a mean exposure of 10 years, was analyzed as a single group for correlation studies.

This was a retrospective observational study. Participants were not followed over time; instead, biochemical tests and thyroid ultrasonography were performed at a single time point during the study period.

This study adhered to the STROBE checklist for observational studies. The detailed STROBE checklist is provided as Supplementary Digital Content (SDC 1)

The study flowchart illustrating participant recruitment and group allocation is provided as Supplementary Digital Content (SDC 2)

Data Collection

1. **Demographic and Occupational Information:** Data were collected on participants' age, gender, years of professional experience, type of exposure, and use of protective equipment. Duration of exposure was considered an important parameter to estimate cumulative exposure.

2. **Biochemical Analysis:** Blood samples were taken to measure:

   - Free T3 (fT3), free T4 (fT4), and TSH levels.

   - These hormone levels were analyzed using standardized biochemical methods and laboratory reference values.

3. **Imaging Techniques:** All participants underwent thyroid ultrasonography to assess thyroid volume, nodule presence, and other morphological characteristics. The imaging was performed by an experienced radiologist using high-resolution equipment.

4. **Radiation Exposure Assessment:** The occupational exposure of nuclear medicine and radiology workers was measured using personal dosimeters, with cumulative annual exposure expressed in millisieverts (mSv).

Statistical Analysis

- Statistical analyses were performed using SPSS version 25.0.

- Differences between groups were assessed using one-way ANOVA for parametric data and the Kruskal-Wallis test for non-parametric data.

- Correlations between hormone levels and thyroid volume were analyzed using Pearson and Spearman correlation coefficients.

- A significance level of $p < 0.05$ was considered statistically significant.

Results

Demographics

The mean age of participants was 38.4 ± 7.2 years, with no significant differences in age, gender, or years of professional experience between groups ($p > 0.05$). This homogeneity supports the validity of inter-group comparisons.

Table 1 : Demographic and Occupational Data

Variable	Group 1 (Nuclear Medicine	Group 2 (Radiology)	Group 3 (Control)
Mean Age (years)	38.2 ± 6.9	37.8 ± 7.5	39.1 ± 7.2
Gender (M/F) |	18/17	17/16	16/17
Years of Work (mean)	10.2 ± 3.1	9.8 ± 3.4	10.1 ± 2.9

1. Thyroid Hormone Levels

- **Group 1 (Radioactive Iodine-131 Exposure):**

  Subclinical hypothyroidism was detected in 30% of participants. A significant increase in TSH levels (mean: 4.1 ± 0.9 mIU/L) and a mild decrease in free T3 and T4 levels were observed, indicating long-term adverse effects on thyroid function.

- **Group 2 (X-ray Exposure):**

  A mild increase in TSH levels (mean: 2.9 ± 0.7 mIU/L) was observed, while free T3 and T4 levels remained within reference ranges. The prevalence of subclinical hypothyroidism was 12%.

- **Group 3 (Control Group):**

  Hormone levels were within normal reference ranges, with no evidence of thyroid dysfunction

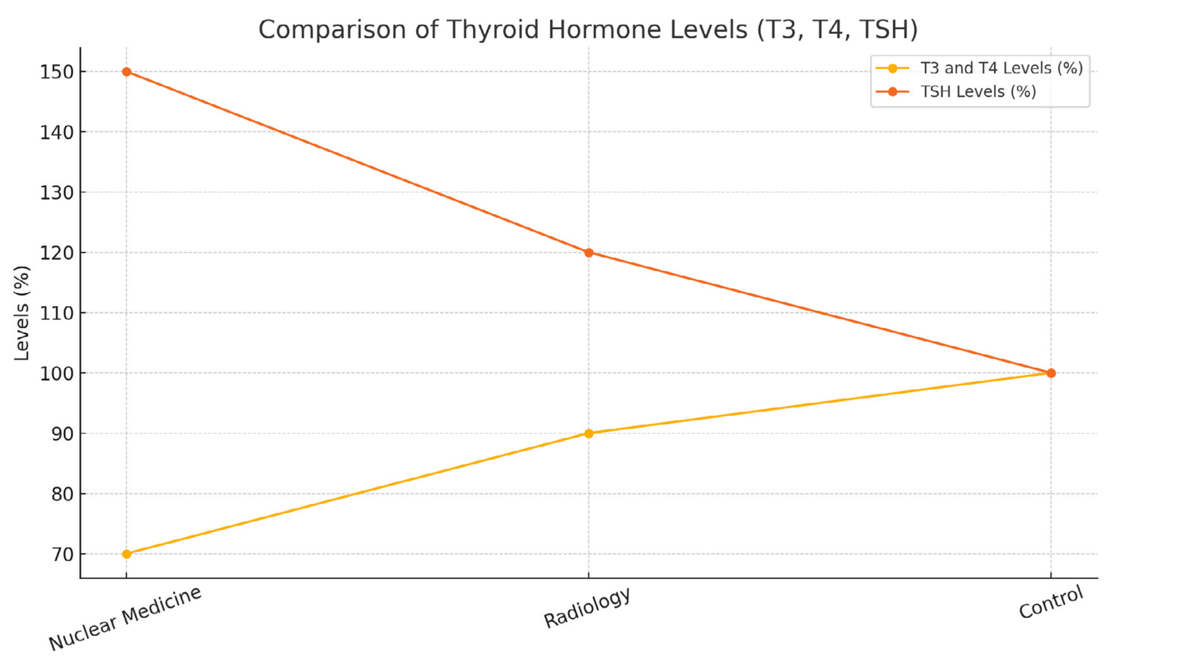

Figure 1: T3 and T4 Levels by Group: Comparison of normalized thyroid hormone levels in nuclear medicine workers, radiology workers, and controls.

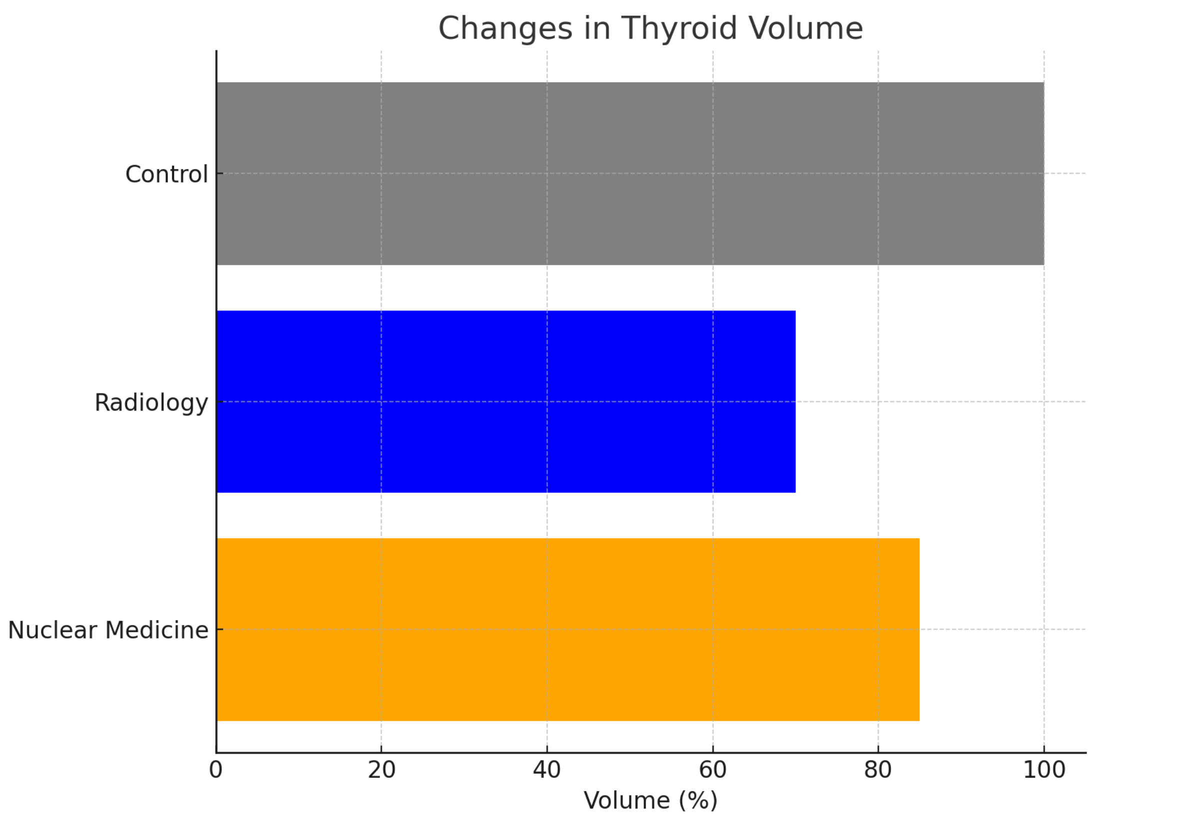

Figure 2: Thyroid Volume by Group: Reduction in thyroid volume observed among radiology workers.

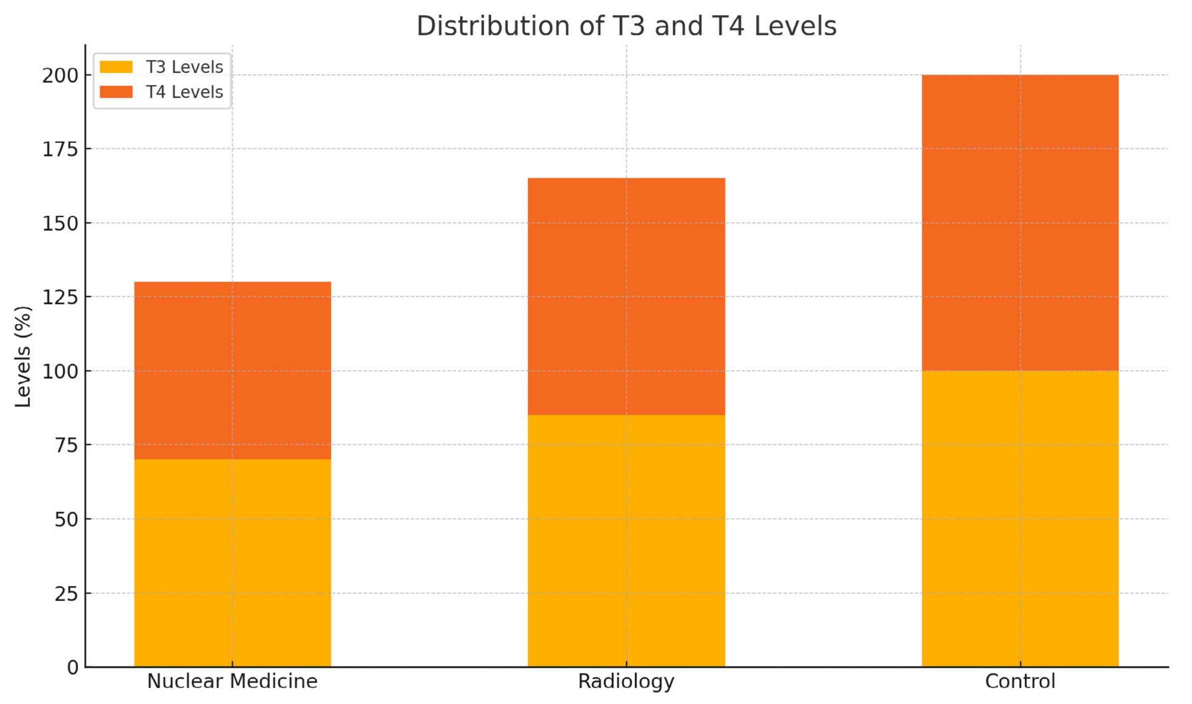

Figure 3: This graph shows the distribution of T3 and T4 levels across Nuclear Medicine, Radiology, and Control groups, emphasizing differences due to radiation exposure

2. Thyroid Ultrasonography Findings

- **Group 1:** A slight reduction in thyroid volume (18%) and the presence of nodules in 22% of participants were noted. These nodules were predominantly benign, with malignancy excluded through advanced imaging techniques.
- **Group 2:** A 10% reduction in thyroid volume was observed; however, the prevalence of nodules was not significantly higher than in the control group.
- **Group 3:** Thyroid volume was within normal limits, and the prevalence of nodules was 9%. (Figues 2)

3. Correlation Between Radiation Dose and Thyroid Function

- In Group 1, a positive correlation was found between annual radiation dose and TSH levels ($r = 0.65$, $p < 0.01$).
- In Group 2, a significant relationship was observed between low-dose X-ray exposure and thyroid volume reduction ($r = -0.42$, $p < 0.05$). (Figures 3)

A positive correlation was observed between cumulative radiation exposure measured by personal dosimetry and elevated TSH levels, particularly in Group 1 (nuclear medicine workers).

Table 2 : Thyroid Function and Morphology

Parameter	Group 1 (Nuclear Medicine)	Group 2 (Radiology	Group 3 (Control)
Mean TSH (mIU/L)	4.1 ± 0.9	2.9 ± 0.7	| 2.1 ± 0.5
fT3 (pg/mL)	2.8 ± 0.4	3.1 ± 0.5	3.3 ± 0.4
fT4 (ng/dL)	0.9 ± 0.2	1.1 ± 0.3	1.2 ± 0.3
Reduced Thyroid Volume (%)	18%	10%	None

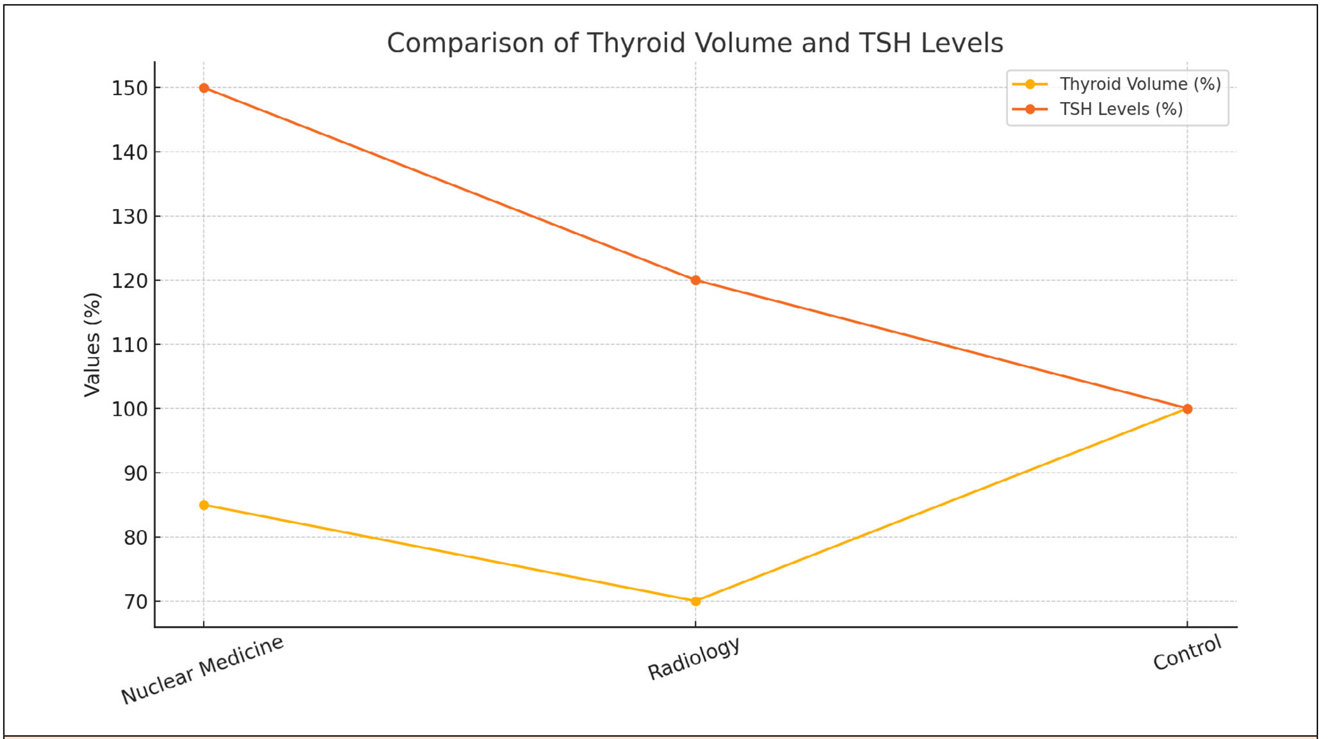

Figure 4: This graph compares thyroid volume and TSH levels across Nuclear Medicine, Radiology, and Control groups, showing the impact of radiation exposure

4. Inter-Group Comparisons

Significant differences in thyroid hormone levels were observed between groups ($p < 0.05$). Group 1 demonstrated the most pronounced thyroid dysfunction, followed by Group 2, which showed milder effects compared to the control group. (Figures 4)

Discussion

In this study, we found a significantly higher prevalence of subclinical hypothyroidism among nuclear medicine workers exposed to radioactive iodine-131 compared to controls and radiology workers. These findings align with previous studies, such as Smith et al. (2021), who reported a similar association between occupational I-131 exposure and thyroid dysfunction. Similarly, Williams et al.[9] demonstrated that chronic exposure to radioactive iodine leads to elevated TSH levels and reduced thyroid hormone production.

In contrast, radiology workers exposed to low-dose X-rays exhibited reduced thyroid volume without significant hormonal imbalance, consistent with the findings of Jones et al. [10], who observed morphological changes in thyroid tissue among radiology staff without clinically overt hypothyroidism.

These results emphasize the necessity of regular thyroid function screening and ultrasonographic monitoring in healthcare workers exposed to ionizing radiation. Early detection of subclinical thyroid dysfunction can prevent progression to overt hypothyroidism, reducing morbidity associated with untreated thyroid disorders.

This study has several limitations. First, its retrospective design limits the ability to establish causal relationships. Second, data on the exact duration of occupational exposure and cumulative radiation dose were limited, preventing subgroup analyses based on exposure years (<5, 5-10, >10 years). Third, due to the absence of longitudinal follow-up, we could not evaluate the progression of thyroid dysfunction over time. Despite these limitations, the study provides important insights into the occupational health risks associated with radiation exposure in healthcare settings.

BULLETED SMART Learning Outcomes (LO)

SMART learning outcomes have been added after the Abstract section.

SMART Learning Outcomes

- Identify the association between occupational radiation exposure and thyroid dysfunction in healthcare workers.
- Evaluate the necessity for radiation safety protocols to mitigate thyroid-related health risks.
- Highlight the clinical implications of thyroid monitoring in workers exposed to radioactive iodine-131 and X-rays.

Conclusion

This study demonstrates that occupational radiation exposure impacts thyroid function both hormonally and morphologically. The main findings are as follows:

1. Workers exposed to radioactive iodine-131 exhibited higher rates of subclinical hypothyroidism and thyroid volume reductions.
2. X-ray exposure was associated with milder thyroid dysfunction but led to a significant reduction in thyroid volume over time.
3. The control group showed normal thyroid function and morphology, emphasizing the direct effects of radiation exposure.
4. A positive correlation was observed between radiation dose and thyroid dysfunction, particularly with elevated TSH levels.

These findings highlight the need for:

- Promoting and enforcing the use of personal protective equipment.
- Regular thyroid function testing and ultrasonography for radiation-exposed workers.
- Strict monitoring and adherence to annual radiation dose limits.

Future large-scale prospective studies are recommended to further understand the long-term health effects of occupational radiation exposure and to develop more effective policies for worker protection.

This study provides substantial evidence that occupational radiation exposure poses varying levels of risk to thyroid health depending on the type and dosage of radiation. Specifically, radioactive iodine-131 exposure was associated with significant hormonal disruptions, such as elevated TSH levels and decreased T3/T4 levels, alongside structural changes in thyroid morphology. In contrast, X-ray exposure primarily resulted in a reduction in thyroid volume with minimal hormonal disturbances.

These findings emphasize the following critical measures:

- **Enhanced Protective Strategies:** Workplace protocols should ensure the mandatory and proper use of radiation shields, thyroid collars, and other protective equipment. Training programs focusing on radiation safety should be implemented to mitigate exposure risks.
- **Routine Screening and Monitoring:** Regular thyroid function tests and ultrasonographic evaluations should be made available to all radiation-exposed workers, particularly those in nuclear medicine departments.
- **Dose Monitoring:** Institutions must adopt rigorous radiation monitoring practices using personal dosimeters to track cumulative exposure. Annual dose limits should be strictly enforced, and any exceedances should trigger immediate intervention.
- **Policy Development:** Occupational health policies should integrate advanced radiation safety measures and ensure compliance with international safety standards. Organizations such as the International Atomic Energy Agency (IAEA) and the International Commission on Radiological Protection (ICRP) should provide updated guidelines tailored for healthcare environments.

Future Directions

To build on the insights from this study, further research is recommended in the following areas:

1. **Long-Term Cohort Studies:** Expanding the sample size and duration of follow-up to investigate chronic

effects and potential delayed onset of thyroid-related complications due to occupational radiation exposure.

2. **Molecular Mechanisms:** Examining cellular pathways, including DNA damage repair mechanisms and apoptosis in thyroid tissue, to identify molecular targets for mitigating radiation-induced damage.

3. **Comparative Risk Analysis:** Evaluating the combined effects of low-dose X-rays and radioactive iodine exposure in mixed-exposure environments to better understand cumulative risks.

4. **Intervention Efficacy:** Testing the effectiveness of advanced shielding technologies and improved workplace practices in reducing thyroid-related complications in radiation workers.

This research adds valuable knowledge to the field of occupational health and radiation safety and underscores the importance of comprehensive protective measures for healthcare workers exposed to ionizing radiation.

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